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Implementation of Free-Fall Lifeboats on Ships

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The free-fall lifeboat is quickly becoming a common lifesaving appliance on ships and offshore facilities. Although a free-fall lifeboat has never been launched from a vessel in distress, free-fall lifeboats were successfully launched and recovered in a seaway during two separate maritime rescues. Discussed in this paper are the basic behavior of free-fall lifeboats, considerations when using free-fall lifeboats on ships, the relative economics of free-fall lifeboat systems compared with conventional davit-launched lifeboat systems, and anticipated improvements in safety afforded by free-fall lifeboats during an emergency.

Introduction and historical perspective

MANY of the risks associated with conventional lifeboat systems have been substantially reduced by the free-fall lifeboat. These risks include impact with the side of the ship during launch, the inability to move away from danger after the launch if the engine does not start, and the inability to launch the lifeboats from the high side of a listing vessel. These problems are minimized with the free-fall lifeboat because it is not lowered into the sea. The free-fall lifeboat falls freely into the sea, generating kinetic energy as it does so. The kinetic energy which is developed propels the lifeboat away from the distressed vessel during and immediately after water entry. The lifeboat moves away from danger even if the engine does not operate.

The first known reference to a free-fall lifeboat is an 1897 patent issued to A. E. Falk of Sweden. The patent drawing depicts an enclosed lifeboat that can slide off the stern of a ship from a height of approximately 3 m (10 ft) [1].[6] In 1939 Captain White of the Bay and River Navigation Company proposed the concept of a free-fall lifeboat (he called it a nonsinkable submarine lifeboat) to the Bureau of Marine Inspection and Navigation of the United States Department of Commerce. This concept was reviewed by the Bureau which concluded that:

> His means of launching lifeboats appears to be inadequate and dangerous, and can in no respect be considered equivalent to the present method of launching such boats. [*The lifeboat*] would strike the water at a terrific speed and would cause considerable shock to the passengers.

Twenty years later in the Netherlands, Joost Verhoef designed and tested a free-fall lifeboat made of aluminum. It was placed in service on a merchant ship in 1961 with a free-fall height of about 6 m. The concept then lay dormant until 1973 when two serious ship disasters occurred. After these accidents, the Nordic maritime authorities commissioned the Norwegian Ship Research Institute to develop an improved lifeboat launching system. The result of this effort was a 34-ft-long free-fall lifeboat that was tested in Hardanger Fjord in 1976 at free-fall heights of up to 20 m. The first manned launch from the stern of a ship occurred in Oresundsvarvet Shipyard in 1977. This installation was formally approved in September 1978 [1].

Today, free-fall lifeboats are in use on cargo ships, tankers, semisubmersible drilling platforms, and fixed production platforms. The heights of free fall range from approximately 6 m on some of the smaller ships to over 30 m on oil production platforms. Although a free-fall lifeboat has never been used in an emergency evacuation, they have been used successfully in two offshore rescues [2]. Over 15 000 people have been launched in free-fall lifeboats during training exercises without a reported injury.

Free-fall lifeboats have not yet been used on passenger ships. These ships generally carry a large number of lifeboats. Locating the required number of lifeboats on the stern of the ship, where the free-fall lifeboat gains its maximum benefit, is not practical. Also, it is generally felt that special training is required to obtain maximum safety from free-fall lifeboats. Such training is not normally available to passengers on a ship.

The purpose of this paper is threefold. First, the basic behavior of free-fall lifeboats will be reviewed and discussed. Second, considerations pertinent to the use of free-fall lifeboats on cargo and tank ships will be presented. Included in the presentation are space requirements for the lifeboats and the relative economics of free-fall lifeboats compared with those of conventional davit-launched lifeboat systems. Third, the anticipated improvement in safety afforded by free-fall lifeboats during a maritime evacuation is estimated. This estimate is based upon available maritime accident data.

Fundamental behavior of free-fall lifeboats

The configuration of a free-fall lifeboat at the beginning of a launch is shown in Fig. 1. The free-fall height is measured from the water surface to the lowest point of the lifeboat when the lifeboat is in its launch position. The primary factors that affect the launch performance of a free-fall lifeboat are its mass and mass distribution, the length and angle of

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[6] Numbers in brackets designate References at end of paper.

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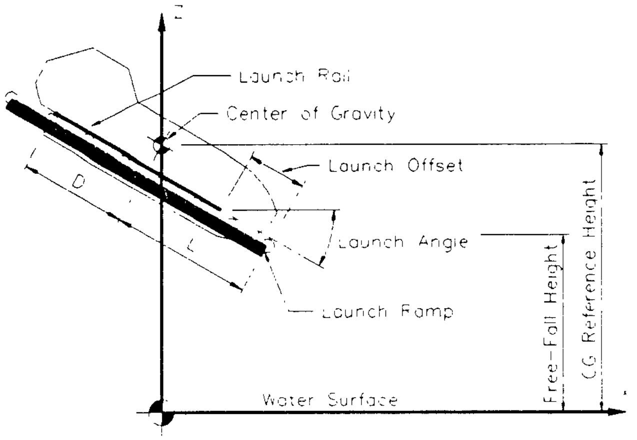


Fig. 1 Parameters of free-fall launch with lifeboat in launch configuration

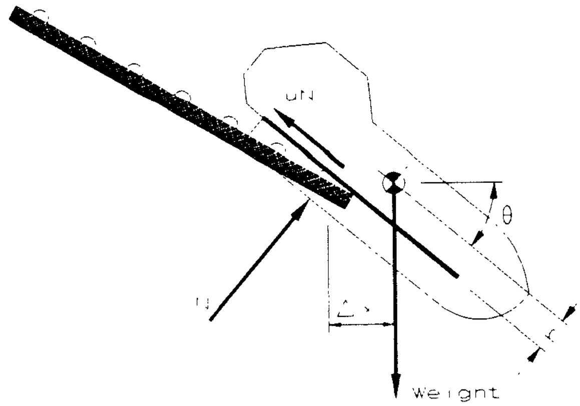


Fig. 3 Geometry of free-fall lifeboat during rotation phase

the launch ramp, and the free-fall height. These parameters interact to affect the orientation and velocity of the lifeboat at the time of water impact, the acceleration forces experienced by the occupants, and the headway made by the lifeboat immediately after water entry.

The launch of a free-fall lifeboat can be divided into four distinct phases: the ramp phase, the rotation phase, the free-fall phase, and the water entry phase. The ramp phase is that part of the launch when the lifeboat is sliding along the launch ramp. The ramp phase ends when the center of gravity (CG) passes the end of launch ramp and the lifeboat begins to rotate; this rotation marks the beginning of the rotation phase. The rotation phase ends when the lifeboat is no longer in contact with the launch ramp. This is the beginning of the free-fall phase; the lifeboat is falling freely through the air. The water entry phase begins when the lifeboat first contacts the surface of the water and continues until the lifeboat has returned to the surface and is behaving as a boat.

During the ramp phase, the only forces acting on the lifeboat are its weight and a friction force between the launch rail and the launch ramp. These forces are shown in Fig. 2. When the lifeboat is released, it begins to accelerate from rest along the ramp. During this time the lifeboat does not rotate; it only gains speed along the launch ramp. The velocity of the lifeboat at the end of the ramp is mostly dependent upon the length of the launch ramp in front of the lifeboat, L. The velocity increases as the distance L increases.

After the CG has moved past the end of the launch ramp, the lifeboat begins to rotate. The forces acting on it during the rotation phase are shown in Fig. 3. Rotation is caused by a couple formed by the weight of the lifeboat and the reaction force between the lifeboat and the ramp. This couple imparts angular momentum to the lifeboat. The primary parameters that affect the behavior of the lifeboat when it is rotating at the end of the ramp are the weight of the boat, the distance D between the CG and the after end of the launch rail, the angle from which the lifeboat is launched, and the velocity of the lifeboat when it begins to rotate. For a particular lifeboat and launch ramp, the distances L and D (as shown in Fig. 1) are dependent upon the location of the CG.

The angular momentum imparted to the lifeboat decreases as the distance L increases. This occurs because the velocity of the lifeboat at the beginning of the rotation phase increases as the distance to the end of the ramp increases. As such, the time during which it rotates—the time during which the couple acts—decreases as L increases. Because the time of rotation is reduced, the angular momentum imparted to the lifeboat is reduced. Likewise, the duration of the rotation, and therefore the angular momentum, increases as the distance to the after end of the launch rail increases. The lifeboat is in contact with the ramp for a longer period of time. The angular momentum increases until the time at which the lifeboat is no longer in contact with the launch ramp. After leaving the launch ramp, the lifeboat continues to rotate at constant angular velocity until it impacts the water.

The geometry of the lifeboat as it impacts the water and the forces acting are shown in Fig. 4. A couple formed by the fluid forces and the weight of the lifeboat causes the angular momentum induced during the rotation phase to be reversed and the boat to return to even keel. This effect can be observed in Fig. 5, which shows the position and orientation of a typical free-fall at the time of the first and second peak

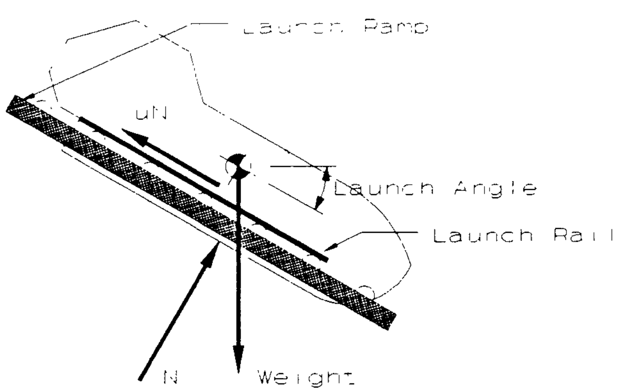


Fig. 2 Forces acting on lifeboat during ramp phase

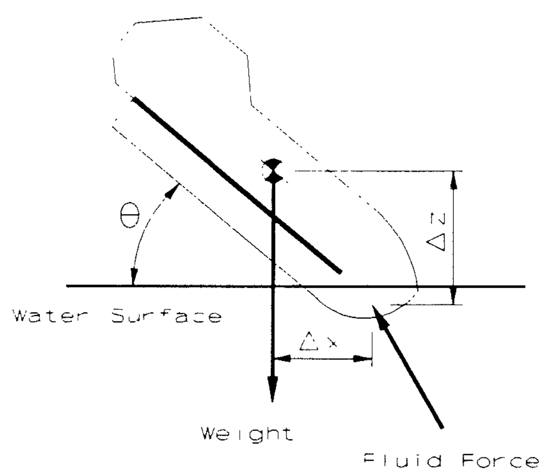


Fig. 4 Geometry during water entry

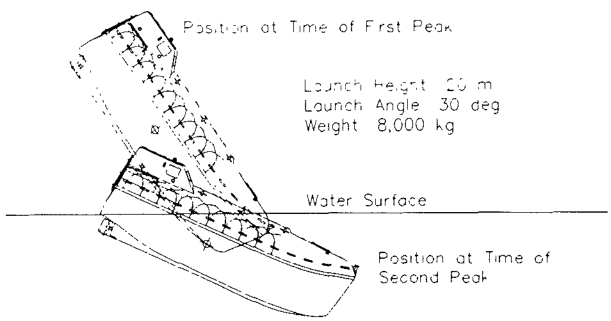


Fig. 5 Orientation at time of first and second peak acceleration forces during water entry

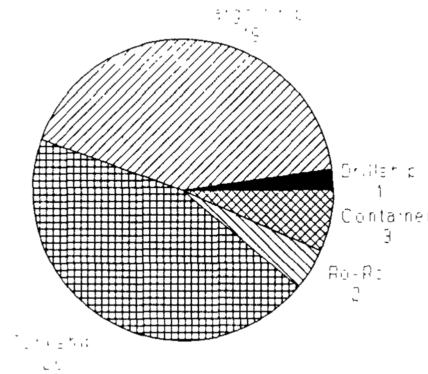


Fig. 6 Breakdown of ship types involved in accidents

acceleration forces. The magnitude of the couple causing the boat to return to even keel is dependent upon several factors, including the location of the CG, the magnitude and direction of the fluid forces, and the orientation of the lifeboat.

As the CG is moved forward, the angular momentum induced during the rotation phase is increased, which causes the lifeboat to enter the water at a steeper angle. Because of the steeper angle and the forward location of the CG, the magnitude of the couple available to overcome the rotation is decreased. If the entry angle is too steep, or if the CG is too far forward, the line of action of the fluid force could pass beneath the CG. This would cause the fluid force to produce an overturning moment instead of a righting moment. In an extreme situation, the lifeboat could overrotate and become inverted during water entry.

Kinematic equations of motion can be written for each phase of the free-fall launch. Such equations have been presented by Nelson & Hirsch [3], Nelson et al [4], Tasaki et al [5], and Boef [6]. These equations of motion form the basis of the launch prediction developed by Nelson & Hirsch [3]. Extensive discussions about the quantitative behavior of free-fall lifeboats have been prepared by Nelson [7], Nelson et al [8,9], Nelson & Khandpur [10], and Boef [6]. The reader is referred to these references for a more thorough discussion of the governing equations of motion and the launch behavior of free-fall lifeboats.

Impact of free-fall lifeboats on safety

Maritime accidents

To estimate how much safety can be improved by using free-fall lifeboats, a review of maritime accidents that have occurred over the past 30 years was conducted by Nelson et al [11]. The purpose of the study was to gather information about ship, sea, and wind conditions during evacuations; the type of lifesaving equipment that was used; and to infer whether a free-fall lifeboat could have been used and if its use would have reduced injury. The data for over 60 ship accidents were obtained from accident investigation reports and newspaper accounts. Because of the sources used, most of the accidents involved vessels registered in the United States. Significant data regarding the lifesaving appliances used in maritime accidents worldwide were not available.

The following discussion is summarized from the discussion by Nelson et al [11] for those accidents involving merchant ships. Data were available for 46 ship accidents. Although not specifically a merchant vessel, the drillship is included in the accident statistics. Passenger and fishing vessel accidents were not included in the analysis because, as discussed previously, free-fall lifeboats are not used on these vessels and probably will not be used on them in the near future.

Figure 6 is a breakdown of the types of ships involved in the ship accidents. Tankers and cargo ships were involved in about an equal number of accidents. Two accidents involved a collision between two ships. The accidents reviewed occurred over a period of 30 years, representing an average of approximately 1.5 accidents per year. About 500 ships of the same type were in the active U.S. fleet during the same period, and these may be used for comparison. The predominant cause of accidents in cargo ships was shifting load. A majority of the accidents in tankships resulted from explosions in the cargo tanks. Other causes included fire and structural failure.

The wind speed and wave height that existed at the time of evacuation are presented in Figs. 7 and 8, respectively. The data are rounded to the nearest increment. Data were not available for all of the accidents reviewed and in some cases the data were estimated from the reports. As can be observed from the data in Figs. 7 and 8, the evacuations occurred predominantly in wind speeds of 50 to 60 mph and wave heights of 15 to 25 ft. In each case, free-fall lifeboats could have been used and would have resulted in a quicker and safer evacuation.

Launch time and distance

Two significant advantages are offered by the free-fall lifeboat during the launch itself. The first advantage is the speed with which the lifeboat can be placed in the water. The reduced time for launching a free-fall lifeboat lies in the time expended from release until the lifeboat is in the water. It is not believed that there are significant differences in boarding a free-fall lifeboat that would make it inherently faster or slower to board than a conventional lifeboat nor are there any intrinsic operating characteristics that would make it

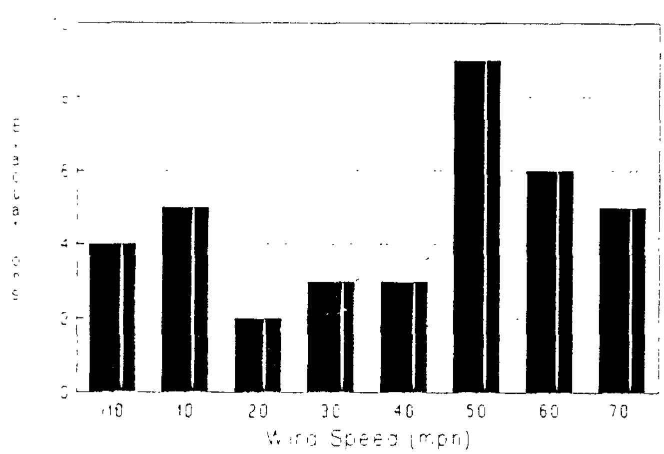


Fig. 7 Wind speed at time of evacuation

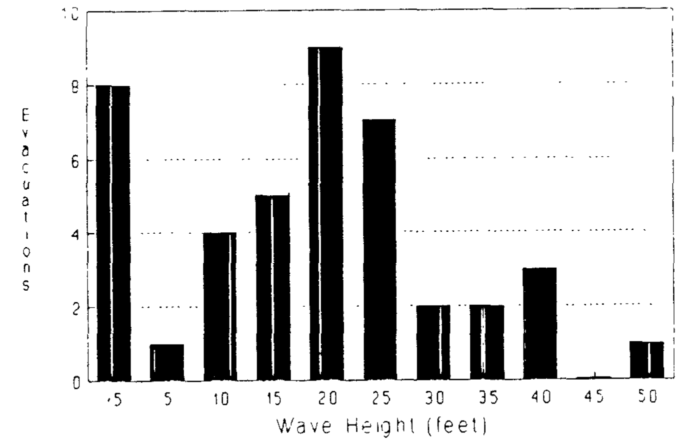


Fig. 8 Wave height at time of evacuation

faster or easier to operate in the water. The differences in launch time occur because, after release, the free-fall lifeboat falls to the water under the influence of gravity whereas the conventional lifeboat is lowered to the sea with a cable.

The time required for free-fall and conventional lifeboats to reach the water after being released is illustrated in Fig. 9. The time for the free-fall lifeboat is based upon an 11 m lifeboat with a fully loaded weight of 7 metric tonnes (t). It was launched from a ramp at an angle of 35 deg with respect to the horizon. The coefficient of friction was taken to be 0.05. The time data were determined using the 1991 launch prediction model FREEFALL (Nelson & Hirsch [3]); the data correspond quite well with available full-scale measurements. The time for the conventional lifeboats was computed using the minimum acceptable speed for lowering a lifeboat by falls. The minimum speed was used because to increase it would require more expensive winches and brakes. The minimum acceptable speed, as specified in SOLAS III–48.2.6, is computed from:

$$S = 0.4 + (0.02 \times H) \tag{1}$$

where H is the height above the water in meters and S is the speed in meters per second.

The second improvement in safety offered by free-fall lifeboats during the launch is the quick movement of the lifeboat away from imminent danger. When a conventional lifeboat is lowered into the water by falls, it is always in close proximity to the vessel from which it is launched. This close proximity makes it vulnerable to the effects of fire, explosion and motion of the vessel. A free-fall lifeboat, on the other hand, is continually moving away from danger as it approaches the water. Figure 10 shows the distance of impact point from the ship for various free-fall heights. These distance data were obtained from FREEFALL for an 11-m-long free-fall lifeboat of 7 t weight.

Additionally, the free-fall lifeboat has the ability to effectively clear the ship by moving away from it. This affords further improvement in safety because initially the free-fall lifeboat is moving further away from danger even if the engine fails to operate properly. A conventional lifeboat must rely on oars to move away from the ship if the engine does not function.

Safety during training and drills

Although training accidents do not occur frequently, there have been injuries due to the accidental operation of the release mechanism before the lifeboat is in the water. Lifeboats have also fallen to the water with people on board when a cable or cable connection has failed. Cable failures occur most often when the lifeboat is being recovered after a drill, but can also occur during lowering.

Cable-related accidents also occur during actual evacuations. In two separate ship accidents, a lifeboat was being lowered during an evacuation into rough seas. The fall at only one end of the lifeboats either released or parted, causing the lifeboat to be suspended vertically and the occupants to fall into the water.

The injuries caused by accidents such as these may be precluded in a free-fall lifeboat. The free-fall lifeboat and the seats in which the occupants ride are designed as a system to protect the occupant from the forces which occur when the lifeboat impacts the water. Free-fall lifeboat systems are designed to impact the water at a relatively high velocity (in the order of 25 m/s). This is not the case for conventional lifeboats, which enter the water at low velocity (on the order of 1 m/s). In conventional lifeboats, the occupants are essentially sitting on benches that render little protection from the effects of impact, particularly impact directed along the spine.

Free-fall lifeboats also have a cable and winch system to recover the lifeboat after drills. This system can also be used to launch the lifeboat when a launch by free-fall is not desired for some reason. When lowered in this manner, the free-fall lifeboat also may be subject to inadvertent release accidents, but in most cases the consequences of such an accident should not be a problem if those on board are properly seated.

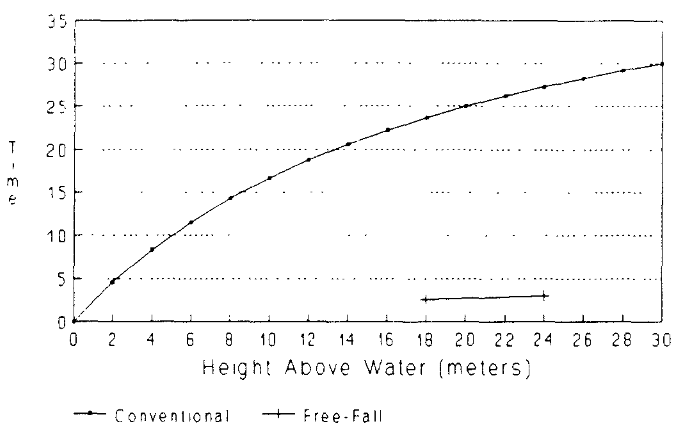


Fig. 9 Time to launch versus height for free-fall and conventional lifeboats

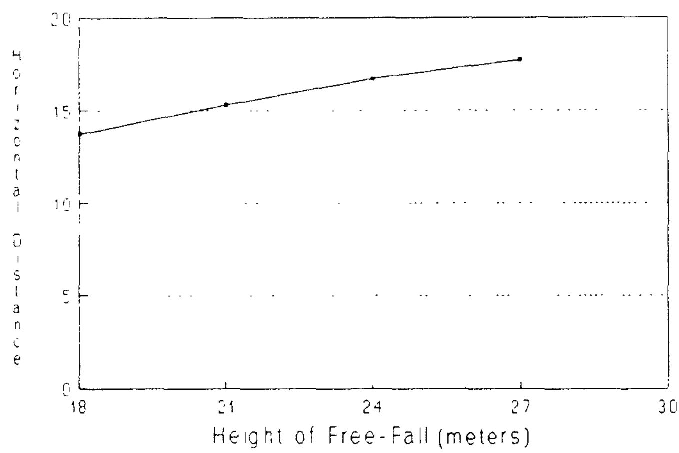


Fig. 10 Distance from vessel that a free-fall enters water

Effect of vessel behavior and attitude

As indicated in Figs. 7 and 8, evacuations tend to occur in relatively high wind speeds and rough seas. Lowering a conventional lifeboat into rough seas can be dangerous. In several of the accidents, the lifeboats impacted the ship during lowering and became damaged. Some of these lifeboats capsized when the occupants were being transferred to other lifeboats. In other accidents the lifeboat was capsized because the lines were not released quickly enough.

In almost half of the accidents, the vessel was reported to have been listing at the time of evacuation. The list and trim of the vessel have a significant effect on the outcome of the evacuation. Conventional lifeboats are placed port and starboard. If the ship is listing significantly at the time of evacuation, use of half the lifeboats is precluded because they cannot be lowered from the high side. Several accident reports indicated that some lifeboats were unusable because the ship was listing. In some cases, the lifeboats on the low side were inaccessible because of fire and flooding.

These problems are significantly reduced with free-fall lifeboats for several reasons. First, the free-fall lifeboat, which is usually located on the stern of the ship, is not significantly affected by list or trim of the vessel. The launch angle would be increased or decreased but the lifeboat would still be usable. Secondly, as shown in Fig. 10, the free-fall lifeboat moves away from the vessel during launch; therefore, the chances of impacting the vessel are minimized. Third, there are no falls or painters to release after a free-fall lifeboat is in the water. Lastly, wind and waves are believed to have little effect on the free-fall lifeboat as it enters the water.

Have conditions precluded a free-fall launch?

Free-fall lifeboats can be launched by free-fall under severe list conditions, but the cable and winch launching systems for free-fall lifeboat may be limited as to the degree of list under which they can be successfully used. This raises the question as to whether a successful evacuation could be made under conditions of ice or debris in the water, or in shallow water, when the ship is also listing. Ice and debris in the water, and shallow water, are conditions under which a launch by falls might be preferred over a free-fall launch.

During the analysis of maritime accidents, Nelson et al [11] concluded that there were no accidents in which free-fall lifeboats could not have been effective during the evacuation. There was no ice or debris reported in the water at the time of evacuation in any of the accidents. Shallow water is usually not a concern since free-fall lifeboats generally do not submerge to a depth greater than the draft of the ship. Except for very shallow water, solid objects of substance are the only thing that would prevent a free-fall lifeboat from being launched by free-fall. Furthermore, there would likely have been fewer casualties if free-fall had been used because of the cable-related accidents discussed previously. There is nothing in the accident reports that would cause one to believe more casualties would have occurred if free-fall lifeboats had been used.

Free-fall lifeboat training

To fully achieve the levels of safety offered by free-fall lifeboats, the crews should be properly trained in the use of the equipment. The Safety of Life at Sea Convention (SOLAS) currently requires such training for all crew members whether the lifeboat is launched by free-fall or by a gravity davit system. Free-fall lifeboat occupants should be comfortable with the concept and knowledgeable about boarding the boat, properly seating themselves, and using the safety harness at their seat.

Free-fall lifeboat training can be conducted at special schools, training centers, or on the vessel. Usually, training centers provide the most extensive and comprehensive training programs. Classroom instruction is combined with hands-on operation during actual free-fall launches. Generally three types of courses are offered at training centers: passenger courses for personnel who may be occupants in a free-fall lifeboat but are not part of the boat's crew; coxswain or captain courses for those crew members who may be assigned those positions; and refresher courses for personnel who have completed free-fall training in the past but are required to reacquaint themselves with the system. Training centers for free-fall lifeboat instruction are the Maritime Training Center (MTC) B.V. in Rotterdam, Robert Gordon Institute of Technology (RGIT) Survival Center in Scotland, See-Berufsgenossenschaft (SBG) Ausbildungs und Trainingsstatte fur Sciffssicherheit in Germany, Norwegian Underwater Technology Center A/S (NUTEC) in Norway, and Trondheim Maritime Hoyskole of Norway. There are currently no free-fall lifeboat training centers in the United States.

Free-fall lifeboat training also can be completed on the vessel using the actual installation if a center is not available. Most free-fall lifeboat manufacturers have trained instructors that can be used for this purpose. The material covered in a shipboard instruction program is much like that of the training centers, except the crew gains firsthand knowledge of the actual equipment they would use in an emergency. Training can be continuously reinforced with regularly scheduled drills and launches on the ship. Information manuals describing the free-fall system and its operating procedures can be kept in the crew recreation room to serve as a source of information about what has been learned.

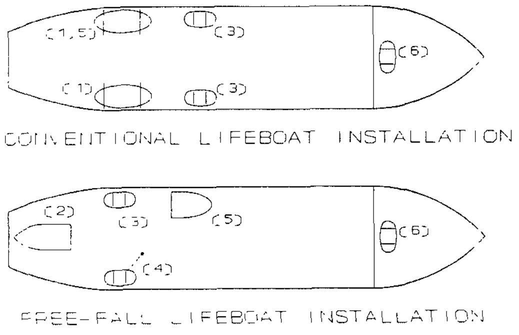
Installation

Space and weight requirements

The International Maritime Organization (SOLAS) and the United States Coast Guard (USCG) currently require cargo ships and tankers equipped with conventional davit-launched lifeboats to have sufficient aggregate seating capacity so that 100% of the persons on board can be accommodated on each side of the vessel. On those vessels equipped with free-fall lifeboats, a single free-fall lifeboat capable of accommodating 100% of the persons on board can be used if the lifeboat is launched over the stern.

In terms of the total quantity of lifesaving equipment required, a free-fall lifeboat installation is approximately the same as a conventional lifeboat installation. Two davits are required for a davit-launched installation, assuming that one lifeboat will also be used as a rescue boat (which is generally the case). A single davit is required for a free-fall lifeboat but an additional davit is required for the rescue boat.[7] However, the davit for the rescue boat is usually a single-arm gravity or mechanical davit which is simpler and more economical than the two-armed davits used with davit-launched lifeboats. A davit-launched life raft is also required on a free-fall lifeboat installation. The davit for the life raft is usually a simple radial-type davit. Figure 11 is a summary of the equipment required for each type of lifeboat installation and

[7] To be used as a rescue boat, a free-fall lifeboat must satisfy all of the requirements for lifeboats and rescue boats. Currently there are no free-fall lifeboats that are also certificated as rescue boats. The primary concerns in this regard are the ability to recover a free-fall lifeboat over the stern in a seaway when the ship is underway and the required time to perform the recovery.



KEY.

ITEM	NUMBER AND CAPACITY REQUIRED	
	FREE-FALL	CONVENTIONAL
1 DAVIT-LAUNCHED LIFEBOAT		2 × 100 % (A)
2 FREE-FALL LIFEBOAT	1 × 100 %	
3 LIFERAFT	1 × 100 % (C)	2 × 100 % (A,B)
4 DAVIT-LAUNCHED LIFERAFT	1 × 100 % (C)	
5 RESCUE BOAT	1	1 (D)
6 ADDITIONAL LIFERAFT	1 (E)	1 (E)

NOTES.

A) ONE SET CAPABLE OF CARRYING ALL PERSONS ON BOARD MUST BE PROVIDED ON EACH SIDE OF THE VESSEL

B) IF LIFERAFTS CAN BE LAUNCHED FROM EITHER SIDE OF THE VESSEL, THEN ONE SET CARRYING 100% OF THE NUMBER OF PASSENGERS ON BOARD MAY BE PROVIDED

C) ONE SET OF LIFERAFT(S) CAPABLE OF CARRYING ALL THE PERSONS ON BOARD MUST BE PROVIDED ON EACH SIDE OF THE VESSEL. RAFTS ON AT LEAST ONE SIDE MUST BE DAVIT-LAUNCHED

D) IF ONE OF THE LIFEBOATS IS ALSO CERTIFIED AS A RESCUE BOAT, AND THE DAVIT MEETS THE REQUIREMENTS FOR A LIFEBOAT/RESCUE BOAT DAVIT, THEN A SEPARATE RESCUE BOAT NEED NOT BE CARRIED

E) AN ADDITIONAL LIFERAFT IS REQUIRED IF THE ACCOMMODATIONS ARE MORE THAN 100 METERS (328 FEET) FROM THE FORECASTLE OR STERN THE LIFERAFT IS TO BE STOWED IN THAT LOCATION

Fig. 11 Comparison of survival craft requirements

the usual location of the equipment on the vessel. This summary is applicable for those vessels over 85 m in length.

Each type of lifeboat system requires some deck area for the installation. The required area includes that necessary for the equipment as well as that necessary for maintenance of the equipment. Tables 1, 2, and 3 give the required deck area and installed weight of each type of lifeboat system. For purposes of this comparison, a typical davit-launched lifeboat and a comparable free-fall lifeboat were used. The free-fall lifeboat installation appears to be more economical than the gravity davit system in terms of estimated deck area. Most of the deck under the free-fall davit is also usable for deck machinery, ventilators, etc. Despite the differences in usable deck space, a free-fall installation is heavier than a davit-launched installation.

Table 1 Overall dimensions of a 26-person free-fall lifeboat installation

System Component	Units Required	Length, m	Beam, m	Area,[a] m^2
Lifeboat	1	7.1	2.5	17.8
Ramp/recovery davit	1	7.4	3.9	28.9
Lifeboat winch	1	0.9	0.5	0.45
Rescue boat	1	6.2	2.6	16.1
Rescue boat davit	1	6.0	2.6	15.6
Rescue boat winch	1	1.4	0.9	1.26

[a] Note that some areas overlap.

Table 2 Overall dimensions of a 28-person gravity-davit lifeboat installation

System Component	Units Required	Length, m	Beam, m	Area m^2	Total Area, m^2
Lifeboat	2	6.9	2.4	16.6	33.1
Lifeboat davit	2	7.6	4.6	35.0	69.9
Lifeboat winch	2	1.4	0.9	1.3	2.5

Table 3 Installation weight of typical free-fall and gravity-davit lifeboat systems

	Free-Fall Lifeboat System		Gravity-Davit Lifeboat System	
System Component	Units	Weight, kg	Units	Weight, kg
Lifeboat(s)	1	4000	2	2107 each
Davit and winch	1	5600	2	3672 each
Rescue boat and davit	1	2400		
12-person life rafts	2	126.5 each	2 or 4	126.5 each
12-person davit life rafts	2	136 each		
Life raft davit and winch	1	1985		
6-person life raft	1	85	1	85
Total weight		14 595		11 896

Economics

As with any equipment cost, there is the initial acquisition and installation cost as well as recurring cost for operations and maintenance. The initial cost to acquire and install a lifeboat system and the annual costs to maintain the system were estimated for specific representative equipment.

Table 4 gives the estimated acquisition costs for typical systems. Shipping costs are assumed to be equal and are not considered for the purpose of this comparison. These cost data were provided by one manufacturer but are thought to be representative of such systems. As shown in the table, the free-fall lifeboat system is \$20 000 less expensive than the conventional lifeboat system. The totally enclosed lifeboat

Table 4 Estimated acquisition costs for a 24-person free-fall lifeboat and a 32-person gravity-davit lifeboat

	Free-Fall System		Gravity-Davit System	
Description	Units	Cost (Each)	Units	Cost (Each)
Lifeboats, davits, and winches	1	\$223 900	2	\$153 000
Rescue boat and davit	1	\$36 000		\$6000[a]
Life rafts (12 pers.)	2	\$5700	4[b]	\$5700
Davit-launched life rafts (12 pers.)	2	\$6200		
Life raft davit	1	\$20 200		
Life raft (6 pers.)	1	\$4700	1	\$4700
Equipment total cost		\$319 400		\$339 500

[a] This is the additional cost for one gravity-davit launched lifeboat certified as a lifeboat/rescue boat and for one specialized winch needed to satisfy recovery speed requirements.

[b] Only two life rafts are required if they can be easily and readily transferred from one side of the ship to the other.

used for the comparison can accommodate 32 persons but at present is the smallest capacity conventional lifeboat system certified by the USCG.

Installation and maintenance costs were also estimated for the two systems based on surveys and discussions with shipyards. A number of shipyards indicated that the man-hours required for installation of a free-fall lifeboat system (including the rescue boat) were the same as or less than that for a two-boat conventional lifeboat system (average time required was 390 versus 460 hours). Only two shipyards indicated that the free-fall lifeboat required more man-hours for installation.

The cost of maintaining the life safety equipment onboard a typical cargo vessel can be divided into two categories: (1) routine maintenance, and (2) regulatory body maintenance. These costs were estimated based upon the experience of various U.S. shipowners and suppliers of lifesaving equipment. Routine maintenance is generally conducted onboard the vessel. For the lifeboat, the routine maintenance consists of periodic operation and inspection of the various components of the lifeboat such as running the engine weekly, checking the battery levels, and checking air pressure in the storage bottles. Routine maintenance of the davit system includes inspection of the lashing and recovery mechanisms, lubrication of the falls and moving parts, and maintenance of the coating systems.

Lifeboat maintenance required by a regulatory body includes the annual stripping of the lifeboat and getting the equipment ready for inspection. Required maintenance for a davit includes opening of the equipment for inspection, replacement or end-for-end exchanging of the falls, and operationally testing the davit.

As there is little difference in maintenance requirements between free-fall and gravity davit-launched (totally enclosed) lifeboats, routine and regulatory body maintenance would be expected to differ little. The same is true for the davit installation. For a rescue boat, maintenance costs are considerably lower because there are no provisions aboard and the davit is much simpler. Little routine maintenance of life rafts is required aboard the vessel, but the rafts must be taken ashore every year for testing and replacement of expired equipment. The davit for the life raft on a free-fall lifeboat-equipped ship requires little maintenance.

The estimated present value of acquisition, installation, and maintenance costs can then be combined to provide a net present value for comparison of the two systems. For this discussion, maintenance costs were assumed to escalate 3% per year and the working life of the vessel to be 20 years. The time value of capital is assumed to be 10%. The estimated present value costs are summarized in Table 5 based upon the required number of components shown in Fig. 11 for each type of installation. The estimated present value for a gravity-davit system is approximately \$535 000 and that for a free-fall system \$482 000. The difference is approximately 10%.

Table 5 Estimated 20-year costs for free-fall and gravity-davit lifeboat installations

	Description of Cost	Free-Fall	Gravity-Davit
Capital costs	system acquisition	\$319 400	\$339 500
	installation	\$13 500	\$17 500
	subtotal capital costs	\$332 900	\$357 000
Maintenance costs	maintenance	\$14 500	\$17 000
	system life	20 years	20 years
	20-year maintenance cost	\$149 100	\$177 600
Total present value		\$482 000	\$534 600

Launch and recovery arrangements

There are three common types of systems for lifeboat recovery and controlled launch using falls: the roller track, the rotating ramp, and the A-frame systems.

Figure 12 shows a rotating ramp system on a test tower. During a controlled launch, the launch ramp pivots about a forward point until it is vertical. This is achieved through the use of hydraulic rams. When the ramp is vertical, the lifeboat is hanging over the water and can be lowered to the water surface by falls.

The roller track system for a free-fall lifeboat works in a similar manner to gravity davits used with conventional lifeboats. Such a system is shown in Fig. 13. The steel davit arm moves on rollers that run along a track underneath the launch ramp. Once the free-fall hook is released and the controlled launch sequence is activated, the davit arm will slide along the ramp with the lifeboat. The rate of descent is controlled by brakes on the winch. At the end of the ramp, the arm will swing the lifeboat over the stern of the vessel so the lifeboat can continue descent towards the water. During recovery of the lifeboat, this sequence of events is reversed. Gravity is the power source needed to launch the lifeboat in this manner, while electric power is required for recovery.

An A-frame launch recovery system, as shown in Fig. 14, consists of a steel davit arm which pivots at the lower, outboard end of the launch ramp with two hydraulic rams. In the stowed position the davit arm lies alongside the lifeboat. When activated for a controlled launch, the hydraulic rams cause the davit arm to swing upward and outboard, which causes the lifeboat to be suspended over the water. The lifeboat can be lowered to the water surface using falls and a winch. As with the other systems, this sequence of events is reversed for recovery.

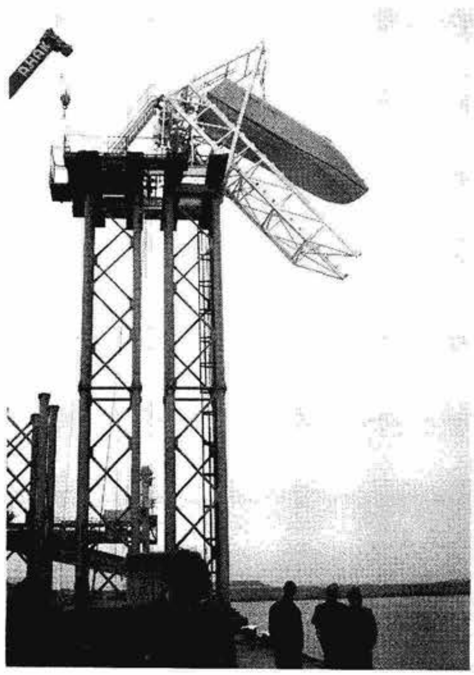


Fig. 12 Rotating ramp launch-recovery system shown on test tower during prototype trials (courtesy Watercraft)

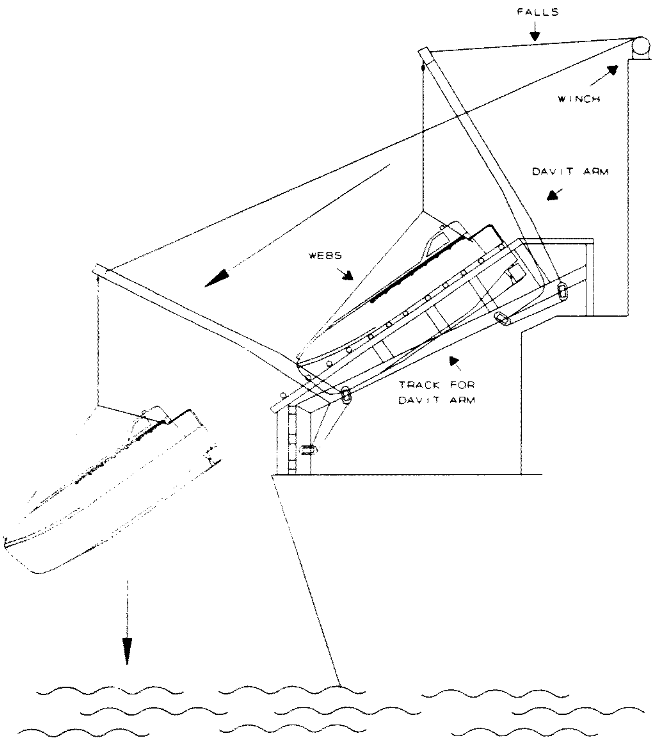


Fig. 13 Roller track launch-recovery system

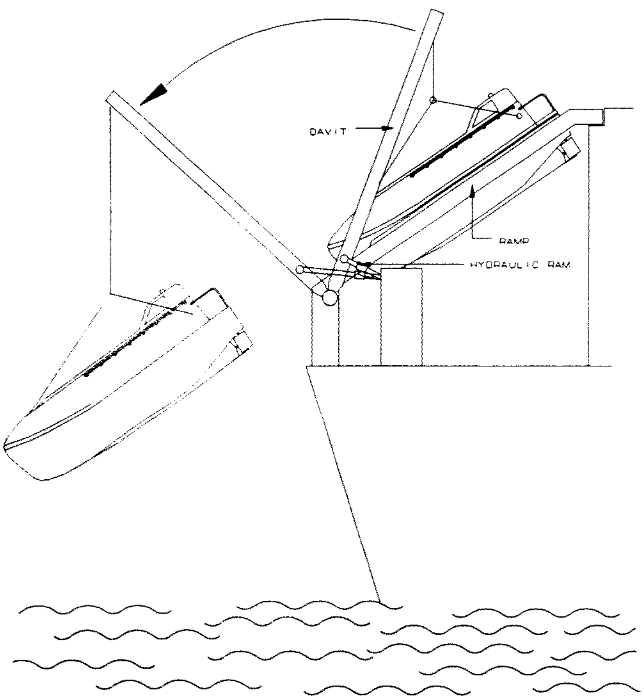


Fig. 14 A-frame launch-recovery system

Conclusion

The design evolution of lifeboats from open wooden boats launched by gravity to totally enclosed free-fall lifeboats has occurred over the last century. European and Asian shipowners have responded to free-fall lifeboats with enthusiasm. The International Maritime Organization, national regulatory authorities, and classification societies have prepared regulations and certification criteria specifically tailored to the unique behavior of free-fall lifeboat systems.

Free-fall lifeboats have a number of advantages when compared with conventional davit-launched lifeboats. These advantages include:

- faster and more efficient evacuation,
- a single stern-mounted lifeboat instead of port and starboard lifeboats,
- means for secondary launching,
- always stowed in the ready-to-launch position,
- boat is propelled clear of the vessel during the launch,
- fewer tasks required for launch,
- safer evacuation, particularly from vessels having a high freeboard, and
- improved economy over a 20-year period.

Currently there are no certificated free-fall lifeboats within the United States, nor are there any training facilities. This situation can change very quickly if the American maritime community, especially ship designers and owners, is informed about the advantages of free-fall lifeboats. When the demand exists, manufacturers are likely to pursue certification of free-fall lifeboats and to market them despite perceived product liability issues. It should be noted that some free-fall lifeboats produced by foreign manufacturers have nearly completed USCG certification requirements.

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Metric Conversion Factors

1 m = 3.28 ft
1 m^2 = 10.76 ft^2
1 kg = 2.2 lb

Appendix 1

Current free-fall lifeboat system manufacturers

C.S.S.C.
Behai Lifeboats
Yan Er Dao
Qingdao
Peoples Republic of China

Ernst Hatecke GmbH
P.O. Box 1107
2168 Drochtersen 4
Germany

Mulder & Rijke BV
P.O. Box 48
1970 AA Ijmuiden
Holland

Pesbo, S.A.
Auda Iparraguirre
48940 Leioa Vizcaya
Spain

Verhoef Aluminium
Scheepsbouwindustrie
& Metaalwarenfabriek
P.O. Box 260
1430 AG Aalsmeer, Holland

Jorgensen & Vik A/S
P.O. Box 9
N-4891 Grimstad, Norway

Greben Shipyard
50270 Vela Luka
Yugoslavia

Fr. Fassmer GmbH
Schiffs-und-Bootswerft
D-2876 Berne 2/Motzen-Wesser
Germany

Harding Safety A/S
N-5470
Rosendal, Norway

Shat Watercraft, Limited
Mumby Road, Gosport
Hampshire, PO12 1AE U.K.

Appendix 2

Summary of numerous free-fall lifeboat characteristics

Key: 1 - Free-fall; 2 - Gravity; 3 - Float-free; 4 - Electric Winch; 5 - Hydraulic Rams; N/A - Information Not Available

Manufacturer	Model/Size	Occupancy	Length (meters)	Breadth (meters)	Height (meters)	Weight Loaded (kgs)	Weight Empty (kgs)	Hull Material	Launch Angle (degs)	Free-Fall Height (meters)	Approvals: Cargo Version	Approvals: Tanker Version	Launch System (See Key)	Recovery System (See Key)	Cost (USD)
Beihai (CSSC)	BH-F7.0	26	7.10	2.86	3.10	6350	4400	GRP	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Beihai (CSSC)	BH-F7.8	30	7.90	2.86	3.10	7100	4850	GRP	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Beihai (CSSC)	BH-F8.6	34	8.70	2.86	3.10	7850	5300	GRP	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Ernst Hatecke	GFF-4.9	8	4.96	1.95	N/A	2540	1940	GRP	30	10	Yes	No	1,2,3,5	4	N/A
Ernst Hatecke	GFF-5.7	15	5.7	2.2	N/A	3625	2500	GRP	30	12	Yes	No	1,2,3,5	4	109,150
Ernst Hatecke	GFF-6.6	18	6.62	2.2	N/A	4260	2910	GRP	30	15	Yes	--	1,2,3,5	4	N/A
Ernst Hatecke	GFF-7.4s	21	7.41	2.2	N/A	4975	3400	GRP	30	18	Yes	--	1,2,3,5	4	N/A
Ernst Hatecke	GFF-7.4b	28	7.4	2.66	N/A	6250	4150	GRP	30	20	Yes	--	1,2,3,5	4	N/A
Ernst Hatecke	GFF-8.1	32	8.15	2.66	N/A	7200	4800	GRP	30	20	Yes	--	1,2,3,5	4	N/A
Ernst Hatecke	GFF-9.9	40	9.9	2.95	N/A	10470	7470	GRP	30	30	Yes	--	1,2,3,5	4	N/A
Ernst Hatecke	GFF-11.5	51	11.5	2.95	N/A	12075	8250	GRP	30	30	Yes	--	1,2,3,5	4	N/A
Ernst Hatecke	GFF-T6.6	17	6.62	2.2	N/A	4770	3420	GRP	30	11.5	--	Yes	1,2,3,5	4	144,550
Ernst Hatecke	GFF-T7.4s	21	7.41	2.2	N/A	5380	3800	GRP	30	14	--	Yes	1,2,3,5	4	N/A
Ernst Hatecke	GFF-T7.4b	28	7.4	2.66	N/A	6550	4450	GRP	30	16	--	Yes	1,2,3,5	4	N/A
Ernst Hatecke	GFF-T8.1	32	8.15	2.66	N/A	7400	5000	GRP	30	15.5	--	Yes	1,2,3,5	4	N/A
Ernst Hatecke	GFF-T9.9	40	9.9	2.95	N/A	10470	7470	GRP	30	22	--	Yes	1,2,3,5	4	N/A
Ernst Hatecke	GFF-T11.5	51	11.5	2.95	N/A	12570	8750	GRP	30	23.5	--	Yes	1,2,3,5	4	N/A
Fr. Fassmer	GAR-T6.8	20	6.82	2.35	1.06	5800	4300	GRP	30	15	Yes	N/A	1,2,3	4	157,511
Fr. Fassmer	GAR-T7.7	34	7.78	2.7	1.21	8170	6070	GRP	30	20	Yes	N/A	1,2,3	4	179,588
Greben	FFL-28	28	7	2.8	3.4	6600	4500	GRP	30	14	Yes	Yes	1,2,3	4	140,000
Greben	FFL-32	32	7.8	2.8	3.4	7700	5300	GRP	30	16	Yes	Yes	1,2,3	4	N/A
Greben	FFL-36	36	8.6	2.8	3.4	8900	6200	GRP	30	18	Yes	Yes	1,2,3	4	N/A
Greben	FFL-40	40	9.4	2.8	3.4	10000	7000	GRP	30	20	Yes	Yes	1,2,3	4	N/A
Greben	FFL-44	44	10.2	2.8	3.4	11100	7800	GRP	30	21	Yes	Yes	1,2,3	4	N/A
Greben	FFL-48	48	1:	2.8	3.4	12300	8700	GRP	30	22	Yes	Yes	1,2,3	4	N/A
Greben	FFL-52	52	11.8	2.8	3.4	14000	10100	GRP	30	23	Yes	Yes	1,2,3	4	220,000
Harding Safety	FF-34	40	10.52	2.95	3.55	12450	9450	GRP	35	20	Yes	Yes	1,2,3	4	N/A
Harding Safety	FF-40	50	12.72	2.95	3.6	16500	12750	GRP	35	N/A	Yes	Yes	1,2,3	4	N/A
Harding Safety	FF-42	60	13.22	3.51	3.95	18000	13000	GRP	35	28	Yes	Yes	1,2,3	4	N/A
Harding Safety	FF-48.1	74	14.6	3.56	5.05	28000	22450	Steel	50	40	Yes	Yes	1,2,3	4	N/A
Harding Safety	FF-700	26	8.22	2.46	3.2	5950-5700	5550	FRP	35	20	Yes	Yes	1,2,3	4	140,000
Jorgensen Vik	GES-22	20	6.77	2.5	3	5000	3500	GRP	N/A	N/A	Yes	Yes	1,2,3	4	180,000
Jorgensen Vik	GES-33	43-45	10.15	3	3.85	11400	8000	GRP	45	40	Yes	Yes	1,2,3	4	345,000 *
Verhoef	FL-10	6-10	6.4	2.3	N/A	N/A	N/A	Alum.	30	12	Yes	No	1,2,3	4 or 5	N/A
Verhoef	FL-15	10-14	7.45	2.3	N/A	N/A	2800	Alum.	30	12	Yes	No	1,2,3	4 or 5	N/A
Verhoef	FL-20	15-20	7.9	2.3	N/A	N/A	4000	Alum.	30	12	Yes	No	1,2,3	4 or 5	N/A
Verhoef	FL-22	8	8	2.4	N/A	N/A	N/A	Alum.	30	16.5	Yes	No	1,2,3	4 or 5	N/A
Verhoef	FL-25	20-25	8.5	2.7	N/A	N/A	4500	Alum.	30	12	Yes	No	1,2,3	4 or 5	223,300 *
Verhoef	FL-30	10-25	9.5	2.9	N/A	N/A	5000	Alum.	35	17.5	Yes	No	1,2,3	4 or 5	N/A
Verhoef	FL-40	26-32	10.5	3.1	N/A	9000	5660	Alum.	35	18.5	Yes	No	1,2,3	4 or 5	357,000 *
Verhoef	FL-50	33-40	11.25	3.25	N/A	9600	6600	Alum.	35	19.5	Yes	No	1,2,3	4 or 5	405,000 *
Verhoef	FL-60	41-60	13	3.5	3.78	14000	N/A	Alum.	35	20	Yes	No	1,2,3	4 or 5	490,000 *
Watercraft	6.0WFF17	17	6.0	2.35	2.32	4500	3255	GRP	30	18	Yes	Yes	1,2,3,4,5	4 or 5	84,000
Watercraft	6.8WFF20	20	6.82	2.35	2.32	5800	4300	GRP	30	18	Yes	Yes	1,2,3,4,5	4 or 5	96,500
Watercraft	7.7WFF34	34	7.78	2.70	2.70	7550	5000	GRP	30	20	Yes	Yes	1,2,3,4,5	4 or 5	116,500
Watercraft	8.5WFF38	38	8.50	2.70	2.70	8600	5750	GRP	30	N/A	Yes	Yes	1,2,3,4,5	4 or 5	128,000
Watercraft	10.15WFF45	45	10.0	3.90	2.75	12450	9075	GRP	30	32	Yes	Yes	1,2,3,4,5	4 or 5	N/A
Watercraft	12.8WFF70	70	12.8	3.80	3.50	15500	10250	GRP	30	N/A	Yes	Yes	1,2,3,4,5	4 or 5	N/A

Note – Cost is for lifeboat only, except where * indicates launch and davit also. For prices quoted in foreign currency, the following conversion rates were used: 1 DM = 0.59 USD, 1 NOK = 0.15 USD